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COLLECTIVE EFFECTS IN INTENSE-FIELD ELECTRODYNAMICS
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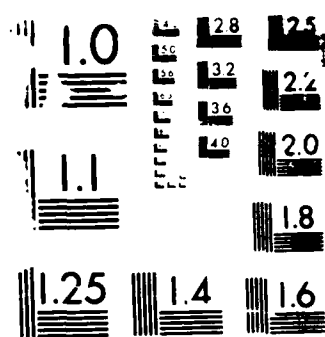
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19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Intense-field, auto-ionization, multiphoton ionization, above-threshold ionization; quasi-continuum, confluence; coherence; golden rule; surface scattering.			
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) We describe the research activities carried out under grant AFOSR-81-0204 and continuations.			

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COLLECTIVE EFFECTS IN INTENSE-FIELD
ELECTRODYNAMICS 1981-1986

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distribution unlimited.

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MATTHEW J. KERPER
Chief, Technical Information Division

Final Report of Research Activities carried out under Grant No.
AFOSR-81-0204 and continuations during the period 15 June 1981 -
14 June 1986

I. Comprehensive list of Research Objectives

To accumulate evidence for collective and coherent effects in the interaction of optical and near-optical radiation with matter, and to develop a theoretical understanding of these effects that is adequate for predictive modeling. The focus of this effort was on continuum transitions such as atomic ionization, molecular dissociation and broadband transitions in solids, where coherence phenomena are not commonly found.

II. Status of the Research

Research objectives were met. Unexpected coherence effects were identified and/or predictive modeling capabilities were developed in several areas. A summary of successful activities follows.

(i) Laser-assisted auto-ionization. It was determined¹ by studying simplified models that transitions to auto-ionizing levels of atoms have the capability to exhibit electron-photon coherence phenomena (until that time unexplored). The most striking of these phenomena is an analog of Autler-Townes splitting, which we showed to imply the possibility of atomic electron "trapping" in an auto-ionizing transition.² We further showed that electron trapping is also possible in a purely continuum-continuum transition.³ The discovery of conditions for trapping is similar to finding a "go, no-go theorem". The trapping conditions identify a domain in which the physical phenomena (radiative absorption and electron emission in this case) are abruptly different from what is conventionally expected.

(ii) Quenching of the Golden Rule of Decay Processes. We discovered⁴ that Fermi's Golden Rule (for the transition rate between a discrete state and a very broad continuum) may break down. A breakdown can occur when the continuum is connected to another state different from the initial state. This is a trivial remark if the other state is discrete like the initial state but quite non-trivial if the other state is a member of a second continuum. This effect was apparently unknown in atomic physics. It appears that this theoretical discovery will have immediate application to experimental work with very high-power lasers now being undertaken⁵ in several US and foreign laboratories -- Livermore, U. of Illinois, ATT Bell, U. of Rochester, U. of Bielefeld, C.E.N. de Saclay (Paris), F.O.M. Institute (Amsterdam), General Physics Institute (Moscow).

(iii) Enhanced Light Scattering near Metallic Surfaces. We have applied techniques developed under (i) above to treat coherently enhanced light scattering from molecules and macroscopic dipole "islands" located near to metallic surfaces⁶, where recent experiments⁷ have exhibited anomalously large cross sections. By including the influence of surface plasmon coupling to continuous degrees of freedom of the substrate material we computed the effect of quasi-Johnson noise as a coherence-destroying mechanism. The framework for further modeling of such scattering situations was established.

References

1. K. Rzazewski and J.H. Eberly, Phys. Rev. Letters 47, 408 (1981); see also P. Zoller and P. Lambropoulos, Phys. Rev. A 24, 379 (1981).
2. K. Rzazewski and J.H. Eberly, ref. 1 and Phys. Rev. A 27, 2026 (1983); see also P.E. Coleman and P.L. Knight, J. Phys. B 15, L235 (1982) and 15, 1957(E) (1982); and Opt. Commun. 42, 171 (1982).
3. Z. Deng and J.H. Eberly, Phys. Rev. A 34, 2492 (1986).
4. Z. Deng and J.H. Eberly, Phys. Rev. Letters 53, 1810 (1984); and JOSA B 2, 486 (1985) and J. Phys. B 18, L287 (1985). See also Z. Bialynicka-Birula, J. Phys. B 17, 3019 (1984) and M. Edwards, L. Pan and L. Armstrong, Jr., J. Phys. B 18, 1927 (1985).
5. For example, see L.A. Lompre, A. L'Huillier, G. Mainfray and C. Manus, JOSA B 2, 1906 (1985) for recent experimental work at Saclay, and references to earlier work elsewhere.
6. D. Agassi and J.H. Eberly, Phys. Rev. Letters 54, 34 (1985); and Phys. Rev. A 34, 2843 (1986).
7. See, for example, W.R. Holland and D.G. Hall, Phys. Rev. Letters 52, 1041 (1984).

III. Cumulative chronological list of journal publications

1. K. Rzazewski and J.H. Eberly
Confluence of bound-free coherences in laser-induced autoionization
Phys. Rev. Letters 47, 408 (1981).
2. J.H. Eberly, J.J. Yeh and C.M. Bowden
Interrupted Coarse-Grained Theory of Quasi-Continuum
Photoexcitation
Chem. Phys. Letters 86, 76 (1982)
3. J.J. Yeh, C.M. Bowden and J.H. Eberly
Interrupted coarse-grained theory of unimolecular relaxation and
stimulated recurrences in photoexcitation of a quasi-continuum
J. Chem. Phys. 76, 5936 (1982).
4. J.H. Eberly, K. Rzazewski and D. Agassi
Influence of Relaxation on Laser-Induced Autoionization
Phys. Rev. Lett. 49, 693 (1982).
5. K. Rzazewski, J. Lewenstein and J.H. Eberly
Threshold effects in strong-field photodetachment
J. Phys. B 15, L661 (1982).
6. K. Rzazewski and J.H. Eberly
Photoexcitation of an autoionizing resonance in the presence of
off-diagonal relaxation
Phys. Rev. A 27, 2026 (1983).
7. J.W. Haus, K. Rzazewski and J.H. Eberly
Laser-induced auto-ionization in an inhomogeneously broadened
medium
Optics Comm. 46, 191 (1983)
8. C.M. Bowden and J.H. Eberly
Aspects of Interrupted Coarse-Graining in Stimulated Excitation
of Vibronic Bands
in Coupled Nonlinear Oscillators, edited by J. Chandra and
A.C. Scott (North-Holland Publishing Co., Amsterdam 1983),
pp. 115-124.
9. D. Agassi, K. Rzazewski and J.H. Eberly
Effects of collisional broadening and radiative recombination on
the time dependence of initial state population of a
photoexcited autoionizing atom
Phys. Rev. A 28, 3648-3650 (1983).
10. Z. Deng and J.H. Eberly
Double-resonance effects in strong-field autoionization
JOSA-B 1, 102-107 (1984).

11. J.W. Haus, K. Rzazewski and J.H. Eberly
Laser-Induced Autoionization: Inhomogeneous Linewidth and Broad-band Laser
in Coherence and Quantum Optics V, edited by L. Mandel and E. Wolf (Plenum, New York, 1984), p.195.
12. Z. Deng and J.H. Eberly
Effect of coherent continuum-continuum relaxation and saturation in multiphoton ionization
Phys. Rev. Lett. 53, 1810 (1984).
13. D. Agassi and J.H. Eberly
Effect of surface dynamical fluctuations on light scattering by a nearby dipole
Phys. Rev. Lett. 54, 34 (1986).
14. E. Kyrölä and J.H. Eberly
Quasicontinuum effects in molecular excitation
J. Chem. Phys. 82, 1841 (1985).
15. Z. Deng and J.H. Eberly
Multiphoton absorption above ionization threshold by atoms in strong laser fields
JOSA B 2, 486 (1985).
16. Z. Deng and J.H. Eberly
Variation of Index in ATI Processes in Fundamentals of Laser Interactions, edited by F. Ehlotzky
(Springer, Berlin, 1985), p. 287.
17. Z. Deng and J.H. Eberly
Variation of above-threshold ionization power law behaviour
J. Phys. B 18, L287 (1985).
18. Z. Deng and J.H. Eberly
Coherent Trapping in Continuum-Continuum Transitions
Phys. Rev. A 34, 2492 (1986)
19. D. Agassi and J.H. Eberly
Dressed-Resonance Representation for Strong Photoexcitation of Continuum States with Application to Laser-Enhanced Autoionization
Phys. Rev. A 34, 2843 (1986)
20. J.H. Eberly
Essential States in Multiphoton Ionization and Electron Scattering in Quantum Optics, edited by A. Kujawski and M. Lewenstein
D. Reidel Publ. Co. (Amsterdam, 1986), p. 126
21. L. Pan, L. Armstrong, Jr., and J.H. Eberly
Comments on the Effect of the Ponderomotive Potential in the Above-Threshold Ionization Processes
JOSA B 3, 1319 (1986)

IV. List of professional personnel, with advanced degrees, name of recipient, title of thesis, date of degree

Sr. Res. Associates

Dr. F.T. Hioe, Dr. K. Rzazewski, Dr. D. Agassi, Dr. J. Javanainen

Sr. Visiting Scholar (no salary)

Lu Qiseng

Res. Assistant

Z. Deng, received Ph.D. degree June 1986, thesis:

"Multiphoton Ionization in Strong Radiation Fields"

V. Interactions (Coupling Activities):

(i) Spoken papers:

1981

1. "Confluence of Coherences in Strong Laser-Induced Auto-Ionization" (with K. Rzazewski)
Invited Paper
Workshop on Photoionization of Excited Atoms and Molecules
JILA, University of Colorado and National Bureau of Standards
Boulder, CO
2. "Nonlinear Coherence Effects in Photoionization Near to Threshold" (with K. Rzazewski)
Invited Paper
Workshop on Photoionization of Excited Atoms and Molecules
JILA, University of Colorado and National Bureau of Standards
Boulder, CO
3. "Coherence and Interference in Strong-Field Photo-Induced Bound-Free Transitions" (with K. Rzazewski)
Contributed paper
European Conference on Atomic Physics
Heidelberg, WEST GERMANY
4. "Theory of Pure Quasi-Continuum Effects in Molecular Dynamics"
Seminar Lecture, Department of Physics
Warsaw University
Warsaw, POLAND
5. "Autoionization in Strong Laser Fields"
Seminar Lecture in Atomic Physics
Department of Physics
Imperial College of Science and Technology
London, ENGLAND
6. "Theory of Quasi-Continuum Recurrence Effects"
Contributed Paper FC 5 (with J.J. Yeh and C.M. Bowden)
Annual Meeting of Division of Electron and Atomic Physics of the
A.P.S., Bull. Am. Phys. Soc. 26, 1327 (1981) New York, New York

1982

7. "Quantum Interferences in Laser-Induced Auto-Ionization"
Atomic Physics Seminar
New York University
New York, NY
8. "Coherence in Auto-Ionization"
Physics Lecture
Department of Physics
University of Arkansas
Fayetteville, AR 72701

9. "Scattered spectra and coherent electronic recombination in bound-free transitions, a model for laser-induced auto-ionization"

Seminar lecture

Istituto Aldo Pontremoli, Università di Milano
Milan, ITALY

10. "Scattered spectra in bound-free transitions, a model for laser-induced auto-ionization"

Seminar lecture

National Institute of Optics
Florence, ITALY

1983

11. "Time Dependence of Initial State Population of a Photo-Ionizing Atom, Including Collisional Relaxation and Radiative Recombination" (with K. Rzazewski and D. Agassi), paper AB 6

Contributed paper, annual mtg. of Divn. of Elec. and Atomic Physics of A.P.S.

12. "Two-Laser Resonances in Photo-Induced Auto-Ionization or Predissociation", (with Zhifang Deng), paper AB 13

Contributed paper, annual mtg. of Divn. of Elec. and Atomic Physics of A.P.S.

13. "Nonexponential Decay in Laser-Enhanced Photo-Detachment" (with K. Rzazewski)

Invited Paper

International Symposium on Unstable States
University of Colorado
Boulder, CO 80309

14. "Induced Autoionization: Inhomogeneous Linewidth and Broadband Laser" (with J.W. Haus and K. Rzazewski), paper MD63

Contributed paper

Fifth Rochester Conferences on Coherence and Quantum Optics
University of Rochester
Rochester, NY 14627

15. "Atoms and Photons in Resonance"

Keynote Lecture

Sixth National Quantum Electronics Conference
University of Sussex
Brighton, ENGLAND

1984

16. "Laser-Enhanced Auto-Ionization and Dressed Resonances" (with D. Agassi)

Invited Paper

Second Topical Meeting on Laser Techniques in the Extreme Ultraviolet
Boulder, CO

17. "Two-Channel Excitation of a Quasi-Continuum"
Colloquium Lecture
University of Texas at Dallas
Richardson, TX
18. "Two-Channel Excitation of a Quasi-Continuum"
Colloquium Lecture
Institute of Physics of the Polish Academy of Science
Warsaw, POLAND
19. "Coupling of Two-Level Coherence to the Quasicontinuum"
(with E. Kryölä), paper AC 5
Contributed paper, annual mtg. of Div. of Elec. and Atomic
Physics of A.P.S.
University of Connecticut
Storrs, CT
20. "Coherent Damping in the Continuum and the Breakdown of Fermi's
Golden Rule" (with Z. Deng)
Invited Paper
US-Japan Seminar on Coherence, Incoherence and Chaos in Quantum
Electronics
Nara, JAPAN
21. "ATI Effects in a Theory with Completely Structureless Continua"
(with Z. Deng)
Contributed paper
International Conference on Multiphoton Processes III
Iraklion, Crete, GREECE
22. "Theory of Above-Threshold Ionization and Free-Free Saturation"
Atomic Physics Seminar
New York University
New York, NY
23. "The Saturation of Fermi's Golden Rule"
Graduate Research Seminar
Department of Physics and Astronomy
University of Rochester
Rochester, NY
24. "Theoretical Problems in Quantum Optics: Photons and Atoms,
Molecules and Surfaces"
Research Overview
Institute of Optics, University of Rochester
Rochester, NY
25. "Continuum-Continuum Relaxation and Saturation in Multiphoton
Ionization"
Atomic Physics Seminar
Oak Ridge National Laboratory
Oak Ridge, TN

26. "Above-Threshold Ionization, A Simple Dynamical Theory"
Atomic Physics Seminar
J.I.L.A., University of Colorado
Boulder, CO

1985

27. "Coherence and saturation in continuum-continuum transitions"
Theoretical seminar
Max-Planck-Inst. f. Quantenoptik
Garching, WEST GERMANY
28. "Variation of k index in ATI processes" (with Z. Deng)
Contributed paper
Seminar on Fundamentals of Laser Interactions
Obergurgl (Ötztal) AUSTRIA
29. "Coherence and saturation in atomic and molecular continuum transitions"
Physics colloquium
Tata Institute of Fundamental Research
Bombay, INDIA
30. "Coherence and saturation in atomic and molecular continuum transitions"
Theoretical physics seminar
University of Hyderabad
Hyderabad, INDIA
31. "Windows of chaos in the AGM model for molecular photoabsorption"
Quantum Optics Seminar/Schloss Ringberg Workshop
Univ. of Munich and M.P. Inst. f. Quantenoptik
Rottach-Egern, WEST GERMANY
32. "Coherence theory of transitions among continuum states of atoms and molecules"
Physics seminar
Istituto di Elettronica Quantistica
Consiglio Nazionale delle Ricerche
Florence, ITALY
33. "Theory of saturation in free-free transitions, and the connection with photo-ionization experiments at high laser intensity"
Theoretical seminar
Istituto di Chimica Quantistica ed Energetica Molecolare
Consiglio Nazionale delle Ricerche
Pisa, ITALY
34. "Essential states in multiphoton ionization and electron-atom scattering"
Special theoretical physics seminar
University of Bielefeld
Bielefeld, WEST GERMANY

35. "Saturation and coherence in continuum transitions"
Laser physics seminar
Imperial College
London, ENGLAND
36. "Coherence and saturation in continuum-continuum transitions and
connection with recent photo-ionization experiments"
Physics colloquium
University of Essen
Essen, WEST GERMANY
37. "Essential-states theory of multiphoton ionization above
threshold"
Atomic physics seminar
Institute of Physics, Latvian Academy of Science
Riga (Salaspils), USSR
38. "Photons, atoms and electrons above threshold"
Theoretical seminar
Technische Universität München
39. "Diagonal matrix elements and free-free transitions in ATI
Processes"
Special atomic physics seminar
C.E.N. de Saclay
Saclay, FRANCE
40. "Continuum saturation and above-threshold photoabsorption"
Invited paper
12th All-Union Conference on Coherent and Non-linear Optics
Moscow, USSR
41. "Essential states in high-intensity scattering and multiphoton
ionization"
Invited paper
Sixth International School of Coherent Optics
Ustron, POLAND
42. "A Proposal for generating tunable XUV radiation via
above-threshold multiphoton ionization"
Special seminar
Laboratory of Laser Energetics
University of Rochester
Rochester, NY
43. "Theory of above-threshold ionization"
Atomic Physics Special Seminar
Lawrence Livermore National Laboratory
Livermore, CA
44. "Orders of magnitude and experimental puzzles"
Special Lecture on Laser Spectroscopy at the High-Intensity
Frontier
Dept. of Physics and Astronomy
University of New Mexico
Albuquerque, NM

45. "Continuum saturation -- Is it observed?"
Special Lecture on Laser Spectroscopy at the High-Intensity
Frontier
Dept. of Physics and Astronomy
University of New Mexico
Albuquerque, NM

1986

46. "Laser Spectroscopy at the High-Intensity Frontier"
Colloquium Lecture, Applied Physics
Stanford University
Stanford, CA
47. "Quantum Optics and the High-Intensity Frontier"
Invited Lecture
Conference on Lasers, Molecules and Methods
Center for Nonlinear Studies
Los Alamos, NM
47. "Quantum Optical Approachs to the Problem of Atoms and Electrons
in Intense Fields"
Invited Lecture
Topical Meeting on Multiple Excitations of Atoms
Seattle, WA

(ii) Advisory activities, contacts with other Institutes/Laboratories:

During the grant period the Principal Investigator served variously as consultant/visiting scientist/advisor to other Institutes and Laboratories on the grant topic as well as other topics. These other Institutes and Laboratories included: US Naval Surface Weapons Center (White Oak), Lawrence Livermore National Laboratory, US Army Missile Command (Redstone Arsenal), Optics Section Imperial College (London), Max-Planck Institut für Quantenoptik (Munich), Los Alamos National Laboratory, Institute for Defense Analyses. Occasions where grant research was discussed at length included:

1983

Lawrence Livermore National Laboratory (LLNL), several visits during year, discussions principally with Dr. B.W. Shore on a number of subjects, including coherence in auto-ionization transitions.

US Army Missile Command (AMICOM), exchange of visits with Dr. Charles M. Bowden to discuss continuum transitions and quasi-continuum modeling of continuum transitions.

Optics Section Imperial College, month of July, discussions with research group of Dr. P.L. Knight about quasi-continuum and continuum transition modeling.

1984

LLNL, several visits during year, discussion with Dr. B.W. Shore and group of Dr. A. Hazi n the topic of intense-laser ionization effects and quenching of Golden Rule.

AMICOM, exchange of visits with Dr. C.M. Bowden concerning quasi-continuum modeling.

1985

Max-Planck-Institut für Quantenoptik, extended consultations as Visiting Scientist and Senior Humboldt Fellow, with theoretical research group of Dr. P. Meystre, particularly with Dr. J. Javanainen and Dr. A. Dulcic, about coherence effects in intense-laser ionization transitions.

LLNL, several visits, discussions with Dr. B.W. Shore, Dr. A. Szöke, and others concerning coherence in transitions to above-ionization-threshold electron energy states.

1986

LLNL, several visits, discussions with Dr. B.W. Shore, Dr. K. Kulander and others on the subject of coherence effects in photo-electron spectra.

VI. New discoveries/patents:

None other than scientific advances detailed above.

VII. Additional statements/information which can help evaluation:

None.

END

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